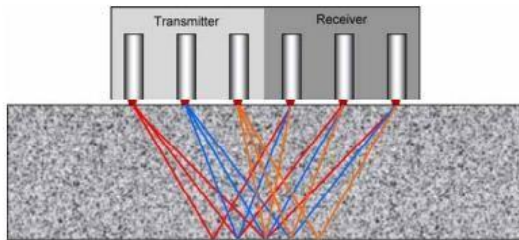


# Testing of a Reinforced Concrete Slab with included Honeycombing and Polystyrene “Delamination” using *EyeCon* (Ultrasonic Pulse-Echo)

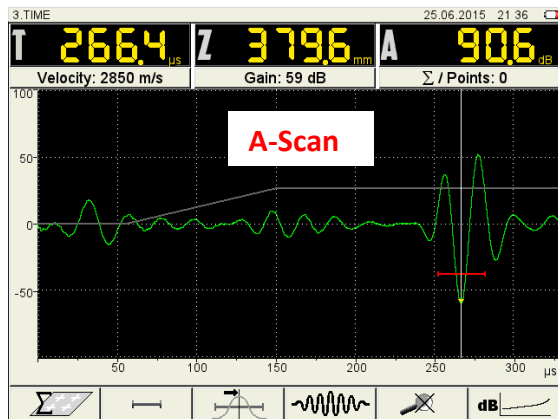
## Ultrasonic Pulse-Echo

*EyeCon* is based on the ultrasonic pulse-echo method using transmitting and receiving transducers in a "pitch-catch" configuration as illustrated below. *EyeCon* uses an antenna composed of 24 dry point contact transducers arranged in a 4 by 6 array as shown to the right. Each transducer is independently spring loaded to conform to surface irregularities. As is shown below, the first three rows of transducers act as transmitters and the other three rows act as receivers. By using the multiple transmitters and receivers, the signal-noise ratio is improved because random reflections from aggregate particles will tend to cancel, while reflections from large concrete-air interfaces will be superimposed. The transducers induce **Shear Waves**, which are a lot more sensitive to air voids than Compression Waves.

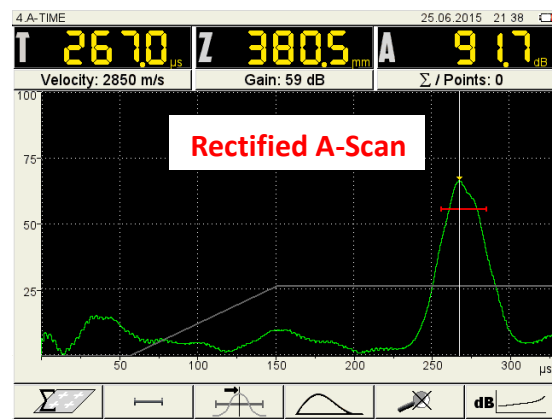


The averaged signal recorded by the receiving transducers is stored in the hand-held unit as a time-domain waveform which can also be converted to depth-domain if the concrete shear wave speed is known. An example of such a waveform is shown below. In this case, the test was done on a solid concrete slab with a thickness of about 380 mm.

The figure on the bottom left side shows the signal amplitude as a function of time (A-Scan). The figure on the right is the rectified version of the signal in which the negative portion of the original signal is plotted as a positive signal. *EyeCon* allows the user to display the signal as recorded originally (left side) or as a rectified signal. The latter is preferred because it allows more detail in the display. These time-domain signals of the received pulse are used to measure the solid thickness or detect the presence of voids or cracks within the test object.

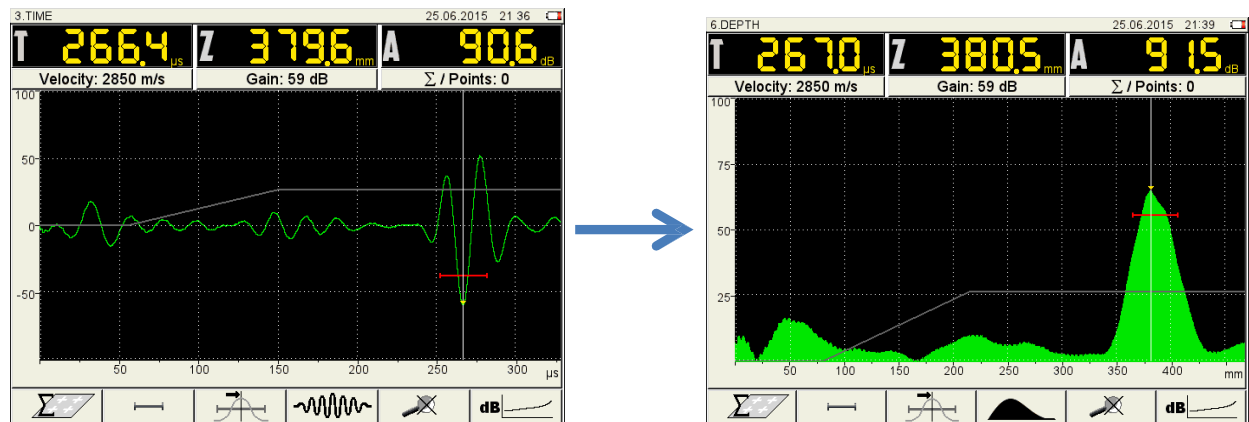


Time,  $\mu\text{s}$



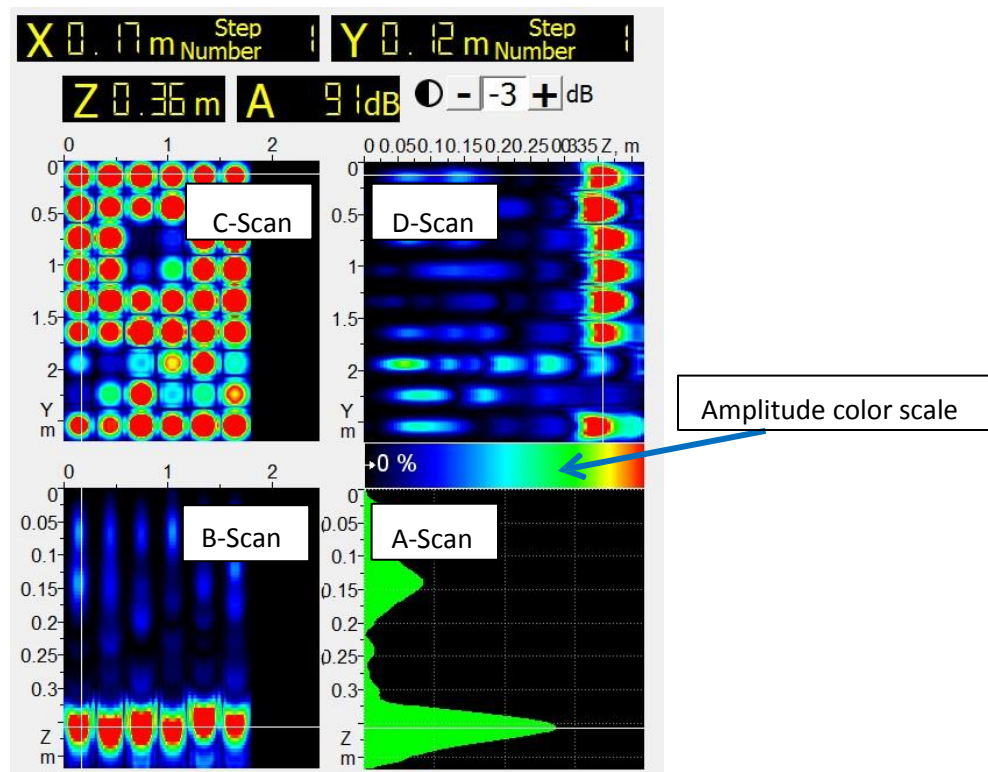
Time,  $\mu\text{s}$

Using the known shear wave speed of concrete, which can be determined by means of calibration, the time domain A-Scan can be shown also as a depth domain A-Scan as shown below.



### PC Software Capabilities

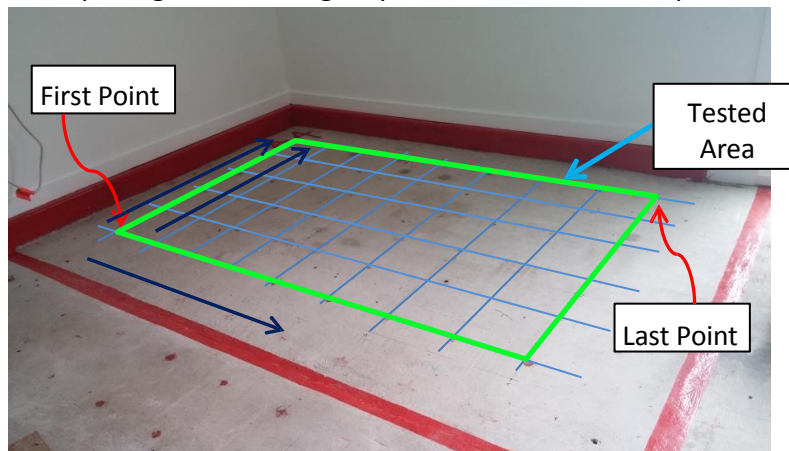
The Software shows the top and side views of the tested slab. All the amplitudes recorded from the tested points are collected to compute the C, B and D scans from the slab. The depth domain A-Scan will be displayed on each of the C-Scan X, Y clicked intersection. At the same time, the C-Scan will display the reflections of the corresponding clicked depth from the A, B and D-Scans. The rate of material change is represented in a color scale.



# Slab Testing Approach

## Preliminary Testing

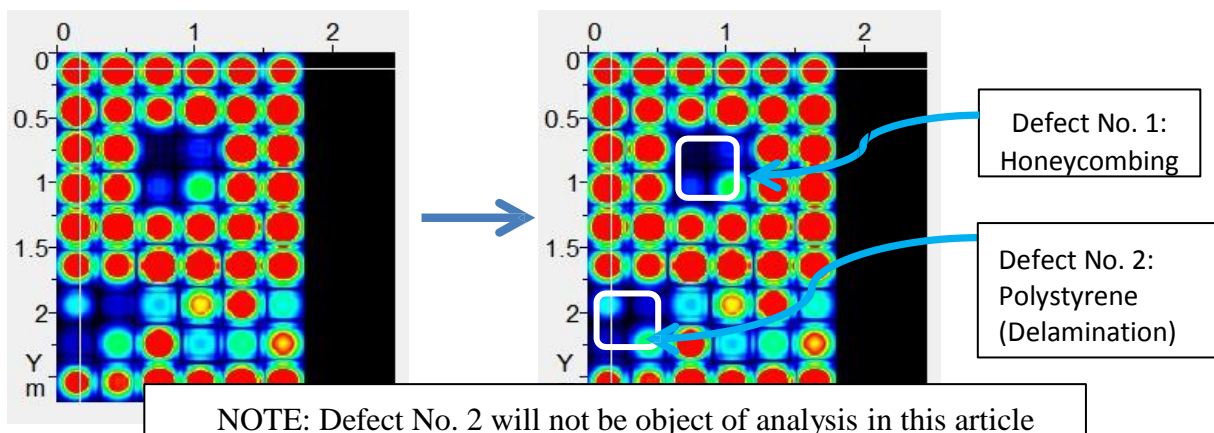
The Ultrasonic Pulse Echo method was used to test a 12 foot by 8 foot reinforced concrete slab. The reinforcement consists of a 5 inch by 5 inch No. 3 rebar mesh at 3 inches (75 mm) deep. The expected thickness of the slab is approximately 15 inches (376 mm). Before testing the whole slab, the equipment was calibrated at areas that showed no defects. After calibration, the shear wave speed to be used to test the whole slab was determined to be 2,850 m/s. In order to quickly assess the slab, a preliminary testing grid was established. The grid had a 1 foot horizontal and vertical spacing. The testing sequence is shown in the picture below.



## Obtained Results

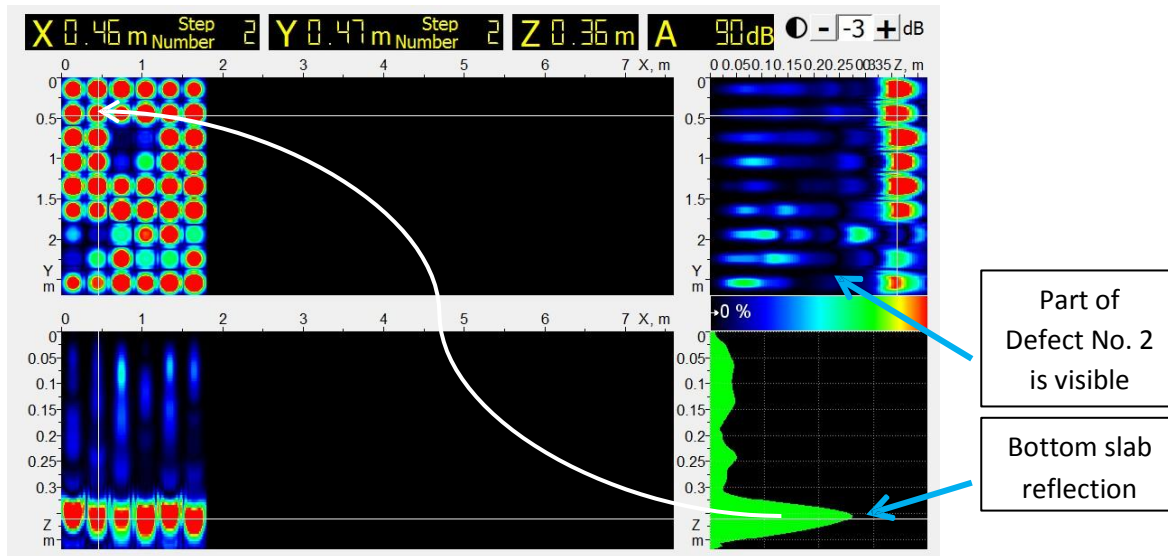
### Preliminary Testing Results

In order to quickly determine where possible defects are located in the X, Y plane, the C-Scan corresponding to the depth of the slab is displayed below. In preliminary assessment, the testing spacing is larger than the dimension of the antenna. Therefore, the results per point won't overlap and will appear as individual red spots. Here, it is obvious that 2 main defects were found. The slab has no backwall reflection where the defects are located because the stress wave was reflected at a shallower depth, the depth of the top boundary of the defect.



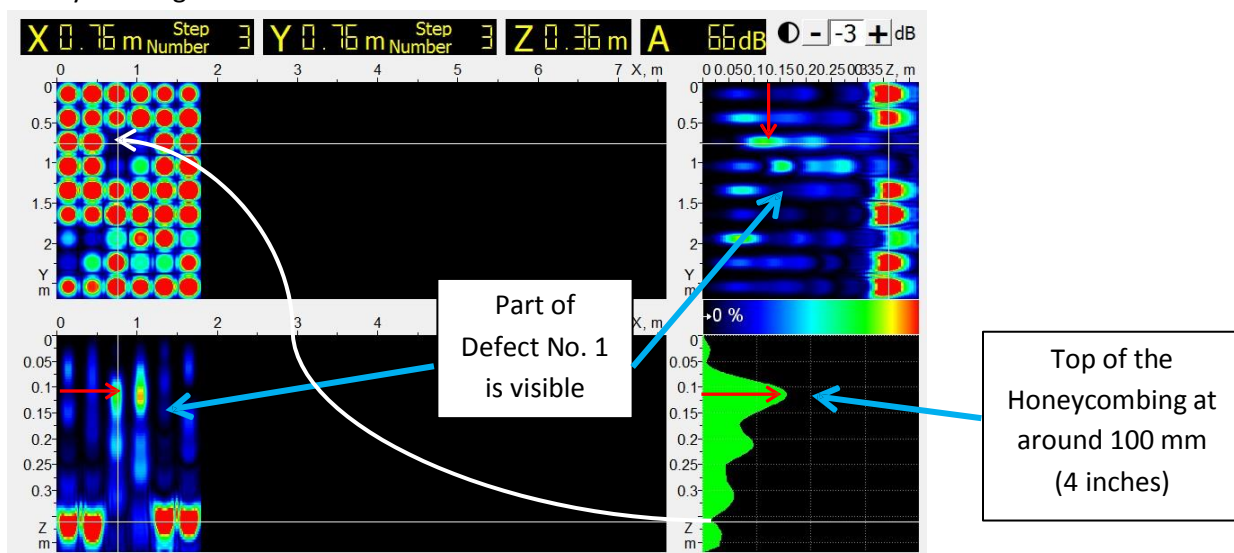
### Analysis at a point on Sound concrete:

The corresponding A-Scan to the steps “2, 2” shows only a high amplitude backwall reflection at the bottom of the slab, at approximately 360 mm, 15 inches. This happens because in sound concrete the stress wave energy is not reflected by internal defects and it is completely reflected only by the bottom end of the slab.



### Analysis at Defect 1, Honeycombing:

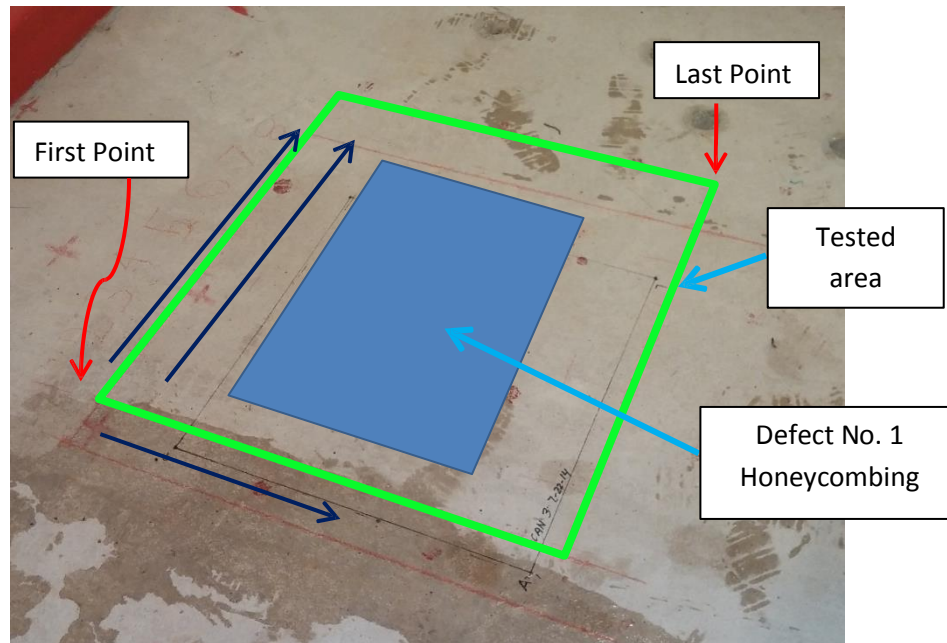
The corresponding A-Scan to steps “3, 3” shows a main reflection at the top of the Honeycombing. In the software, the centroid of the top reflection of the Honeycombing is at a depth of around 100 mm (4 inches). Other reflections are observed as the shear waves are reflected from the inside of the Honeycombing.





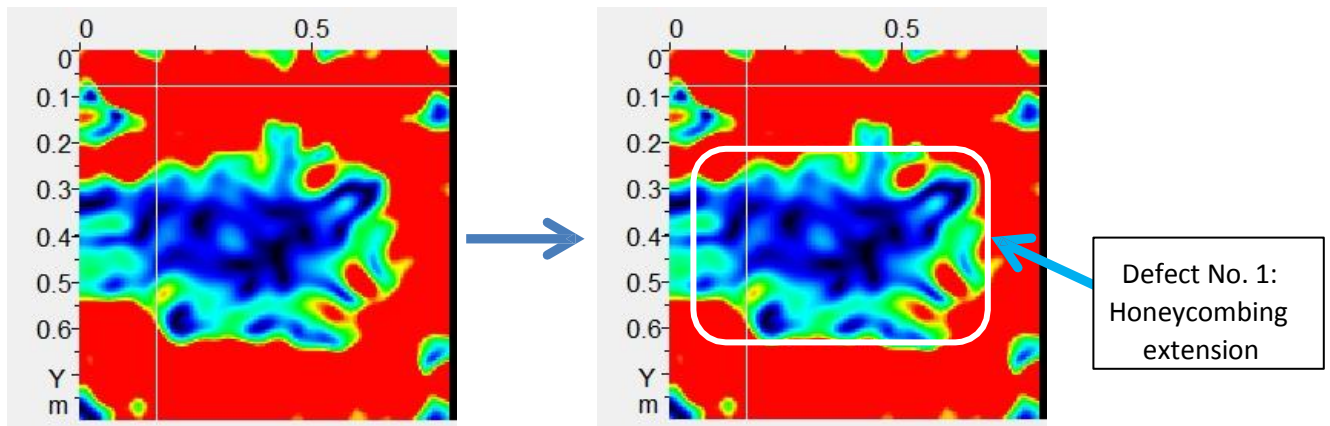
## Detailed Testing

After determining where defects are located, a more detailed testing grid map was tested over defect No. 1 (Honeycombing). In this case, the testing surface consisted of a small grid with 100 mm (approximately 4 inches) horizontal and vertical spacing.



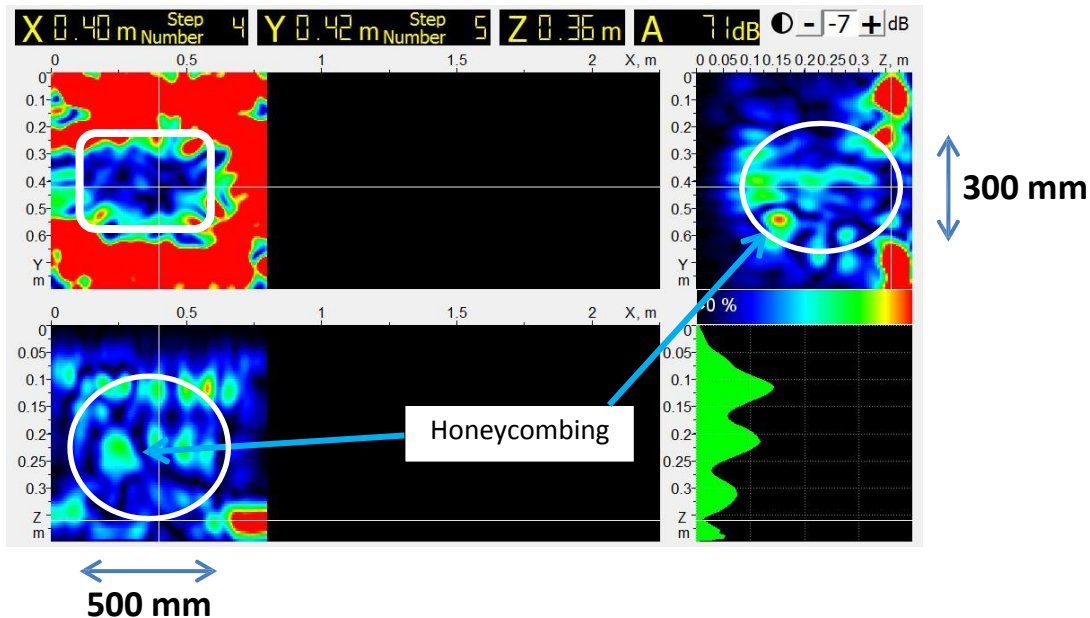
## Detailed Testing Results

In order to quickly determine the extension of the Honeycombing in the X, Y plane, the C-Scan corresponding to the depth of the slab is displayed below. In detailed assessment, the testing spacing is equal than the dimension of the antenna. Therefore, the results per point are continuous and the obtained image won't have uncovered areas. Here, it is obvious that the Honeycombing covers almost all the tested area. The slab has no backwall reflection where the Honeycombing is located because the stress wave was reflected at a shallower depth, the depth of the top boundary of the Honeycombing.



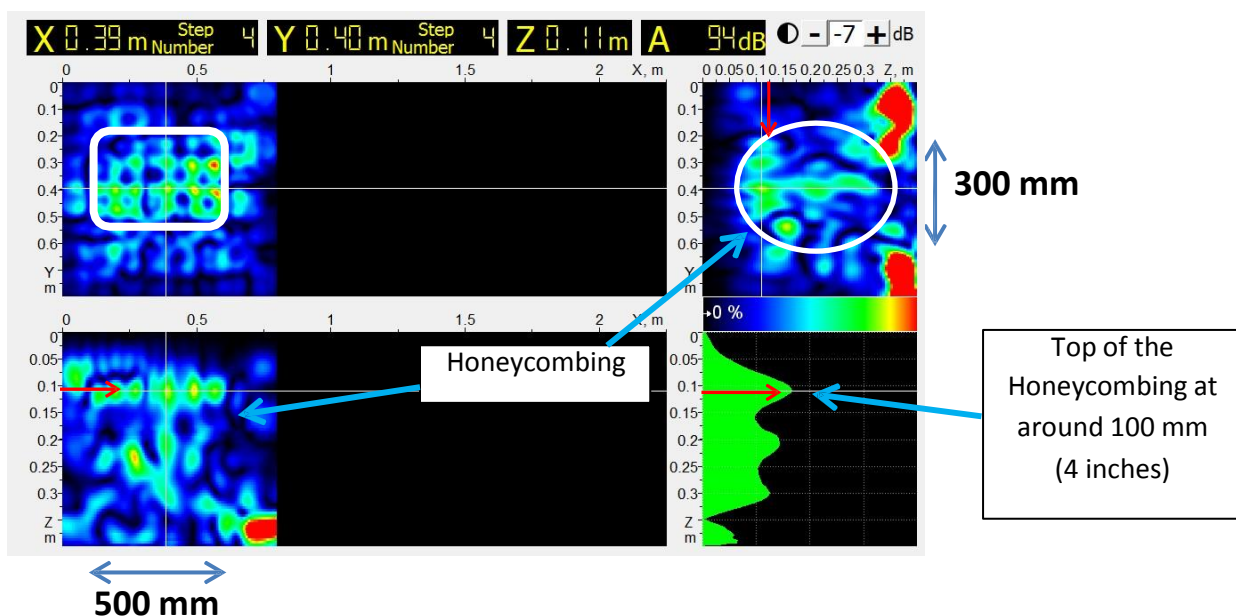
### Analysis at the bottom of the Honeycombing:

The corresponding A-Scan to the center of the Honeycombing shows very low reflection at the bottom of the slab. In other words, there is no backwall reflection because most all the stress wave energy was reflected along the depth of the honeycombing. The same phenomenon occurs along all the bottom surface of the honeycombing. From here, it can be determined that the bottom of the honeycombing covers an rectangular area of approximately 500 mm by 300 mm ( approx 20 inch by 12 inch).



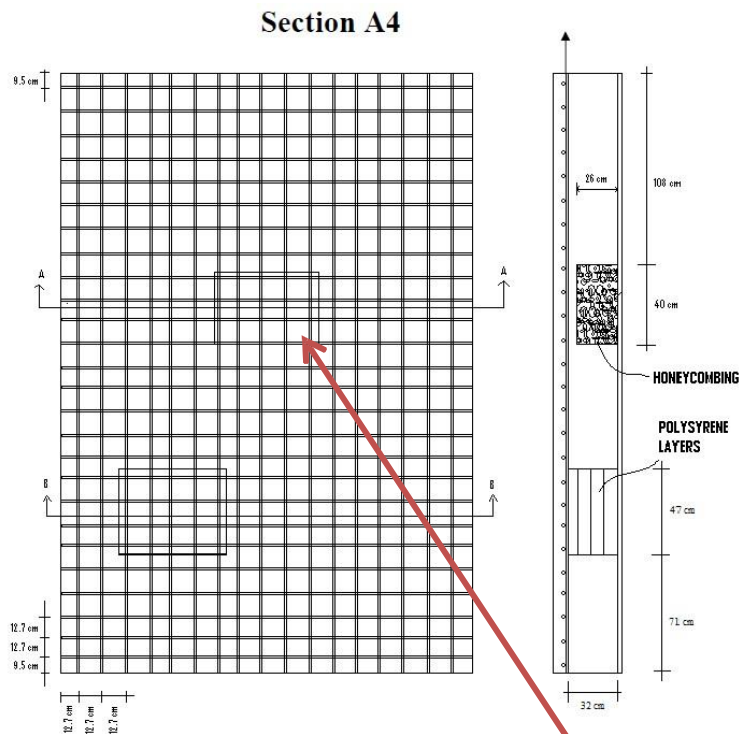
### Analysis at the Top of the Honeycombing:

The corresponding A-Scan to the center of the Honeycombing shows very high reflection at around 100 mm (4 inches) below the slab surface. In other words, the top surface of the Honeycombing is located at 4 inches below the surface and has a total high of 15 inch – 4 inch = 11 inches.

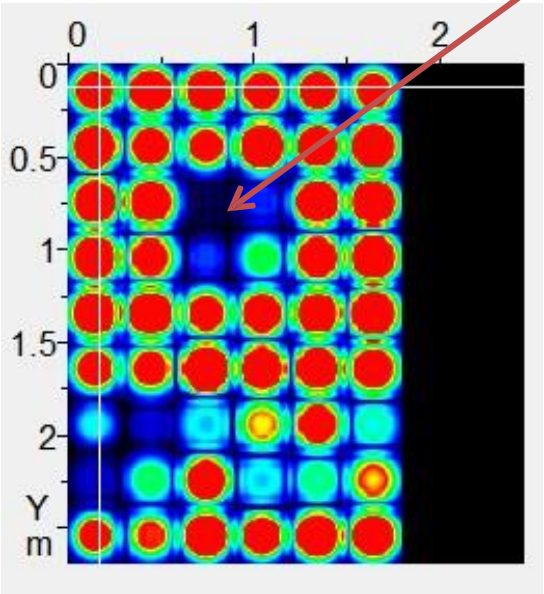


Construction Plans vs NDT Findings

Construction Plans



NDT Findings with EYECON (Ultrasonic Pulse-Echo)



Defect No. 1  
Honeycombing

## Conclusions

**EyeCon** is a portable, small and unexpansive system best suitable for air related reflection interfaces. These reflective interfaces can be Backwalls (which gives the Thickness) or defects such as internal air pockets, honeycombing and delaminations.

Some Material properties can also be assessed by measuring the Wave Speed of the tested surface.

In a controlled area the calculated wave speed may be an indicator of the apparent density or compacting degree, nevertheless this procedure requires a known thickness.

Locating defects with **EyeCon** depends highly on the testing grid spacing. If preliminary testing is to be conducted, the consultant in charge of the assessment will have to evaluate the structure and determine what will be the best grid spacing.

The degree of understanding and definition depends on the type of encountered defects. Thicknesses, single air pockets, delaminations and honeycombings can easily be defined accurately. However, if two or more voids are overlapped below the antenna during an individual test, the result will only give a general idea of where the defects are. To overcome this as much as possible, small spacing grids are suggested.

The repeatability of results obtained with this system is easily achieved. If the grid spacing is well defined before testing, **EyeCon** offers a high user to user repeatability since the test itself is not motion dependent.



